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Post-nesting Migrations of loggerhead turtles (*Caretta caretta*) from Wassaw Island, GA.

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Introduction

Southeastern U.S. beaches are considered one of the most important nesting areas for loggerhead turtles (*Caretta caretta*) in the Atlantic. Nesting occurs primarily from North Carolina through Florida with the densest concentration located in Florida. Tagging studies indicate that most loggerheads return to the same beaches (Bjorndal et al. 1983) or adjacent beaches (Bell and Richardson 1976) to nest in successive breeding seasons. These observations of strong nesting site fidelity suggest that loggerheads along the southeastern U.S. coast are genetically structured. However, it wasn't until recently that molecular tools needed to answer this question were available. Encalada et al. (1998) sampled loggerhead turtles from throughout the southeastern U.S. and determined that loggerheads nesting in North Carolina, South Carolina, Georgia, and north Florida (NC-NFL) are genetically similar to one another, but genetically distinct from loggerheads nesting in south Florida and other nesting beaches in the Western Atlantic (Brazil, Mexico) and Mediterranean (Greece).

The conservation implications of Encalada et al's (1998) findings are important in managing U.S. sea turtle populations. First, there are now two recognizable genetically distinct loggerhead stocks (management units) nesting along the southeastern U.S. coast. The south Florida stock is relatively robust. However, the NC-NFL stock is significantly smaller, comprising only 9 % of the loggerhead nesting in the southeastern U.S. (Sears et al. 1995). Second, there are numerous human impacts that threaten loggerhead turtles throughout their range and determining their relative impacts on the two loggerhead stocks is difficult because we know little about the distribution of post-nesting loggerheads from either stock. This gap in our knowledge is especially significant for the small NC-NFL stock because losses from this group due to human impacts threaten its recovery to a much greater degree.

Little is known about the post-nesting distribution and migrations of NC-NFL loggerheads. Elucidating their migration patterns could provide information helpful toward determining potential and real threats to the turtles in their aquatic habitats. This information is needed to assist management and recovery efforts of this threatened species. We conducted a study of the migratory behavior of post-nesting loggerheads from Wassaw Island, Georgia to determine the locations of their migratory routes and foraging grounds. Wassaw Island is located in the Wassaw National Wildlife Refuge (Fig. 1). The number of loggerheads nesting on Wassaw is small. Since 1973, the annual number of nesters has ranged from 18 to 63 turtles (Williams and Frick 1997).

Methods

We attached Telonics, Inc. model ST-6 back-pack style transmitters to 5 loggerhead turtles to track their post-nesting movements. All transmitters had a temperature sensor and a sensor (two external electrodes) that acted as a "saltwater switch." The saltwater switch activated transmission mode and initiated collection of surface/submergence data when the transmitter was in air. Two transmitters also had a pressure transducer to determine depth of dives. The depth sensor recorded the number of times turtles occurred at specific depth intervals. There were 4 depth intervals: 0 m - 10 m, 10 m - 50 m, 50 m - 100 m, 100 m - 500 m. Transmitters collected and stored data in fixed 12 h periods which roughly corresponded to day (0700 h - 1900 h): night (1900 h - 0700 h) light cycles. The transmitter duty cycle was 8 h on, 52 h off to prolong transmitter lifespan.

When transmitters were "on" and a turtle was at or near the surface, the transmitter sent a signal (401.650 Mhz) approximately every 60 seconds. One of two polar-orbiting NOAA Tiros-N satellites received the signal when the satellite was within view of a transmitter. Satellites distributed transmission data to a network of ground communication links. Argos, Inc. Data Collection and Location Service processed the data and distributed results to users. These data included the transmitter identification code, internal transmitter temperature, duration of the last submergence prior to transmission, mean time submerged, number of submergences (> 10 seconds), and for transmitters with pressure transducers, the number of times a turtle was at a particular depth interval. When there were multiple transmissions received from a transmitter during a single satellite pass, Argos calculated a location (latitude and longitude). Argos calculated transmitter locations from the Doppler shift in the transmitted frequency detected by a satellite as it approached and then moved away from a transmitter. In addition, Argos also provided a location class (LC) for each location. The LC indicated the quality of the location estimate. When LC was equal to "a" or "b" there was no estimate of location accuracy. For LC = 1 the estimated accuracy was ≥ 350 m and < 1000 m, LC = 2 was ≥150 m and < 350 m, and LC = 3 is < 150m.

We restrained post-nesting turtles on the beach in a plywood box frame that fit around the turtle and prevented it from crawling. We cleaned the anterior end of each turtle's carapace with water, followed by acetone. We used coarse-grained sandpaper to create a rough surface on and adjacent to the second vertebral scute of the carapace and on the base plate of the transmitter. We poured 4 oz. of commercially available polyester resin into a plastic container, added liquid hardener according to product directions (more or less 8 drops per 0.03 L resin), stirred the mixture for 3 min, and applied it to the second vertebral scute of the turtle and to the base plate of the transmitter with a paint brush. We then placed the transmitter on the second vertebral scute. If air spaces were present between the carapace and base plate, we used small strips of fiberglass pipe insulation to fill the open space. We painted resin on the anterior (below the external electrodes), posterior, lateral and top sides of the transmitter. We placed long strips of fiberglass cloth (approximately 7 cm x 20 cm) on the sides of the transmitter, with half the width overlapping the transmitter and the other half overlapping the carapace. We then attached a wider strip of cloth (15 cm x 20 cm) laterally across the top of the transmitter. We applied resin liberally to fiberglass cloth. We mixed a second batch of resin in a fresh plastic container, but this time added more liquid hardener to the mixture (2-3 more drops/0.03 L). We applied another layer of fiberglass cloth strips and resin. Resin cured in approximately 3 h and we released turtles from the beach.

Results

We attached transmitters to post-nesting turtles in mid to late July 1997 (Table 1). We chose this time period because July was the height of the nesting season on Wassaw Island and the end of the nesting season. This enhanced our chances of finding 5 loggerheads that were finished nesting for the season and would begin post-nesting migrations.

We received transmissions from all of the turtles for 4 - 5 months after their release (Table 1). Overall, we received very few transmissions (Table 2). The number of total transmissions received per turtle ranged from 1 to 32 transmissions. Only 30 % of the transmissions received provided location estimates and most of the locations (83%) were low quality estimates (Table 2).

Location estimates indicated that post-nesting loggerheads traveled long-distances from Wassaw Island (Table 2). We calculated distances traveled from location estimates and they represented minimum estimates of the total distance traveled during the tracking period. Distances ranged from 156.8 km to 1,458.1 km. Four of the five turtles migrated north after the nesting season (Figs. 2 - 6). Turtle 11358 migrated north along the coast to northern North Carolina and then did not transmit a good location for 3 months (Fig. 2). December locations indicated that this turtle was located off of southern North Carolina. Turtles 11359, 19571 and 19572 migrated to the Delmarva (Delaware-Maryland-Virginia) Peninsula (Figs. 3,5,6). Turtle 11359 was first located off of southern North Carolina and then migrated north along the North Carolina coast (Fig. 3). This turtle did not transmit a good location for 2 months. In October, turtle 11359 transmitted from the Chesapeake Bay, Virginia. By the end of October, turtle 11359 had migrated south and then remained offshore of North Carolina for the remainder of her tracking duration. Turtle 19571 migrated north, but because she transmitted only two locations we were unable to determine whether she migrated along the coast (Fig. 5). Turtle 19571 was first located in the Albemarle Sound, N.C. and then off of southern N.J. one month later. Turtle 19572 was first located offshore of North Carolina and then migrated north to the Maryland-Virginia border, remaining offshore most of the time (Fig. 6). By the end of August, turtle 19572 moved west close to the Virginia coast, and then did not transmit a location for almost 2 months. Turtle 19572 eventually moved south and was last located offshore of North Carolina in October. Turtle 11360, the only turtle that migrated south from Wassaw Island at the end of the nesting season, was located only once, close to shore at the Georgia-Florida border (Fig. 4).

Surface/submergence data collected by the transmitters indicated that the loggerheads spent 94 % to 96 % of their time submerged (Table 3). Turtles 19571 and 19572 transmitted dive depth data (Table 4). These turtles spent most of their time at depths between 0 m - 50 m, however there were a few instances when they dove as deep as 50 m - 100 m and one instance when turtle 19572 dove to 100 m - 500 m. Turtle 19571 spent most of her time between 10 m - 50 m, while turtle 19572 occurred primarily between 0 m -10 m. Dive depths corresponded well with the locations of turtles. For instance, while turtle 19571 was in Albemarle Sound, N.C. she occurred at depths of 0 - 10 m. When she was located offshore N.J., turtle 19571 occurred at depth of 10 m - 50 m.

Conclusions and Recommendations

There are two causes for the low number of transmissions and low quality location estimates we received. First, the transmitter duty cycle we used was insufficient; the transmitters were programmed to turn on 8 h and off 52 h. This duty cycle works well with turtles that spend a lot of time at the sea surface (Plotkin 1998), but is not advisable for turtles that stay submerged for long periods of time. Our transmitters were originally built and programmed for deployment on olive ridley turtles (*Lepidochelys olivacea*) (Mervis 1997) that spend a lot of time at the surface during migration (Plotkin 1998). Second, the loggerheads we tracked spent most of their time submerged, thus limiting their time at the surface and their chances of contacting a satellite. If the transmitters we used had been turned on more often and had a lower repetition rate ($\leq$ 45 sec), we would have received more transmissions, more locations and better quality locations.

The post-nesting migratory routes of the loggerheads we tracked from Georgia indicated that important foraging habitats lie in the coastal waters north of Georgia. Three of the five loggerheads migrated to the Delmarva region suggesting that this area provided important foraging opportunities. Tagging studies conducted on Georgia and Florida nesting beaches documented recoveries of post-nesting loggerheads in N.J. and Delmarva coastal waters (Bell and Richardson 1976, Meylan et al. 1983). However, because there have been only a few tagged individuals recovered, the Delmarva region was not recognized as an important habitat for adult loggerhead turtles. The importance of Delmarva waters to juvenile loggerheads is well established. Studies conducted in the Chesapeake Bay (Byles 1988, Keinath et al. 1987), Delaware Bay (Spotila et al. 1998) and nearshore waters (Shoop and Kenney 1992) indicate that loggerheads are seasonally abundant in the region.

Despite the demonstrated abundance of sea turtles in northeast U.S. waters (Shoop and Kenney 1992), and the observation that turtles occur there with greater regularity each year (Morreale and Burke 1997), the importance of this region remains unrecognized and recovery efforts for sea turtles lag far behind recovery efforts in southeast U.S. waters. This is best illustrated in the recovery plan for U.S. populations of loggerhead turtles (NMFS 1991) where none of the recovery objectives or tasks planned for this species take place in northeast U.S. waters.

Sea turtles in the northeast U.S. may have been overlooked in management and conservation planning perhaps because they are believed to be predominantly juvenile, non-reproductive turtles with low reproductive value. However, the current study and two other on-going tracking studies conducted by researchers in Georgia and South Carolina (e.g. Sally Murphy, SCDNR and Sarah Mitchell, NOAA) document that reproductively active loggerheads do occur in northeast U.S. waters. Our results are exciting for several reasons. First, they demonstrate the importance of Delmarva waters to sea turtles with the highest reproductive value. Second, these results highlight the importance of Delmarva waters as critical seasonal foraging habitat where turtles can feed on benthic invertebrates such as blue crab (*Callinectes sapidus*), horseshoe crab (*Limulus polyphemus*) and other marine invertebrates (Lutcavage et al. 1985, Dodd 1988, Plotkin et al. 1993). Finally, our results partially fill in the gap in our knowledge regarding post-nesting migrations of loggerhead turtles from the NC-NFL stock. Potential threats to the NC-NFL stock lie in the coastal waters north of Georgia. Recovery efforts for this stock will need to occur at a regional level, extending far north of Georgia nesting beaches if they are to be effective.

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Table 1. Date of transmitter attachment and transmitter longevity for post-nesting loggerhead turtles (*Caretta caretta*) tracked from Wassaw Island, Georgia.

Turtle ID	PTT type	Date of transmitter attachment	Date of last transmission
11358	Regular	Jul 17, 1997	Dec 18, 1997
11359	Regular	Jul 18, 1997	Dec 17, 1997
11360	Regular	Jul 18, 1997	Nov 12, 1997
19571	Pressure transducer	Jul 19, 1997	Dec 29, 1997
19572	Pressure transducer	Jul 26, 1997	Nov 4, 1997

Table 2. Number of transmissions and location classes and minimum distances traveled (km) for post-nesting loggerhead turtles (*Caretta caretta*) tracked from Wassaw Island, Georgia.

Turtle ID	Total # transmission	# LC a,b	# LC 1,2,3	Minimum distance travelled (km)
11358	15	7	0	1,182.0
11359	32	9	3	1,458.1
11360	1	1	0	156.8
19571	21	1	1	1,009.9
19572	27	6	1	1,409.1

Table 3. Submergence data for post-nesting loggerhead turtles (*Caretta caretta*) tracked from Wassaw Island, Georgia.

Turtle ID	# 12 hr periods	$\bar{x}$ Time submerged (min)/12 hr period	SD	% Time submerged
11358	13	679	30.1	94 %
11359	19	689	16.9	96 %
11360	12	686	7.1	95 %

Table 4. Dive depth data for 2 post-nesting loggerhead turtles (*Caretta caretta*) tracked from Wassaw Island, GA. Numbers indicate the percent occurrence at specific depth intervals for the entire tracking period.

Turtle ID	0 m - 10 m	10 m - 50 m	50 m - 100 m	100 m - 500 m
19571	38.1	57.5	4.4	0.04
19572	80.5	19.5	0.05	0

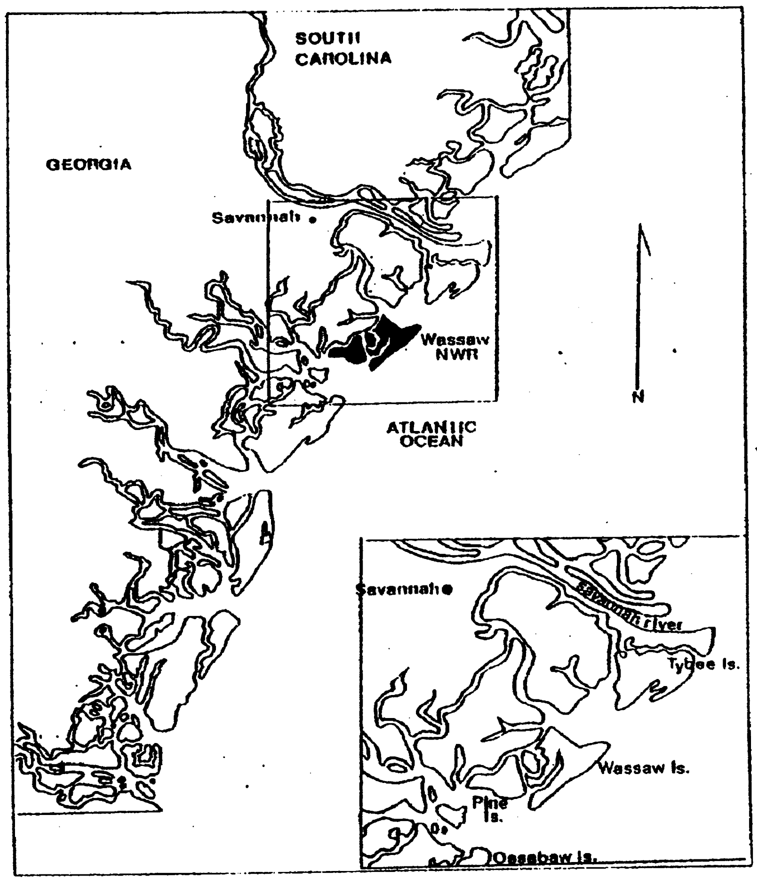

Figure 1. Wassaw National Wildlife Refuge

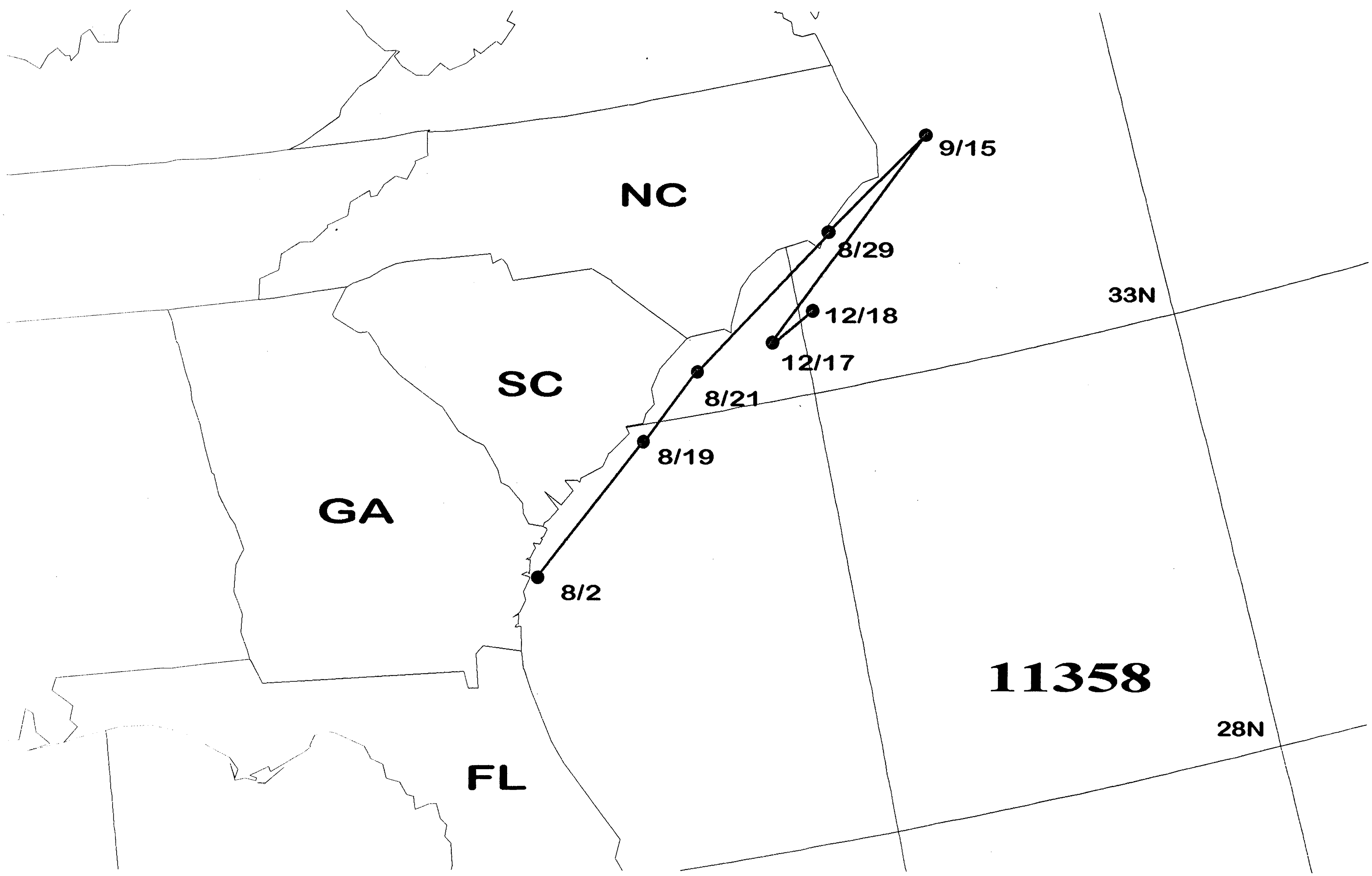

Figure 2

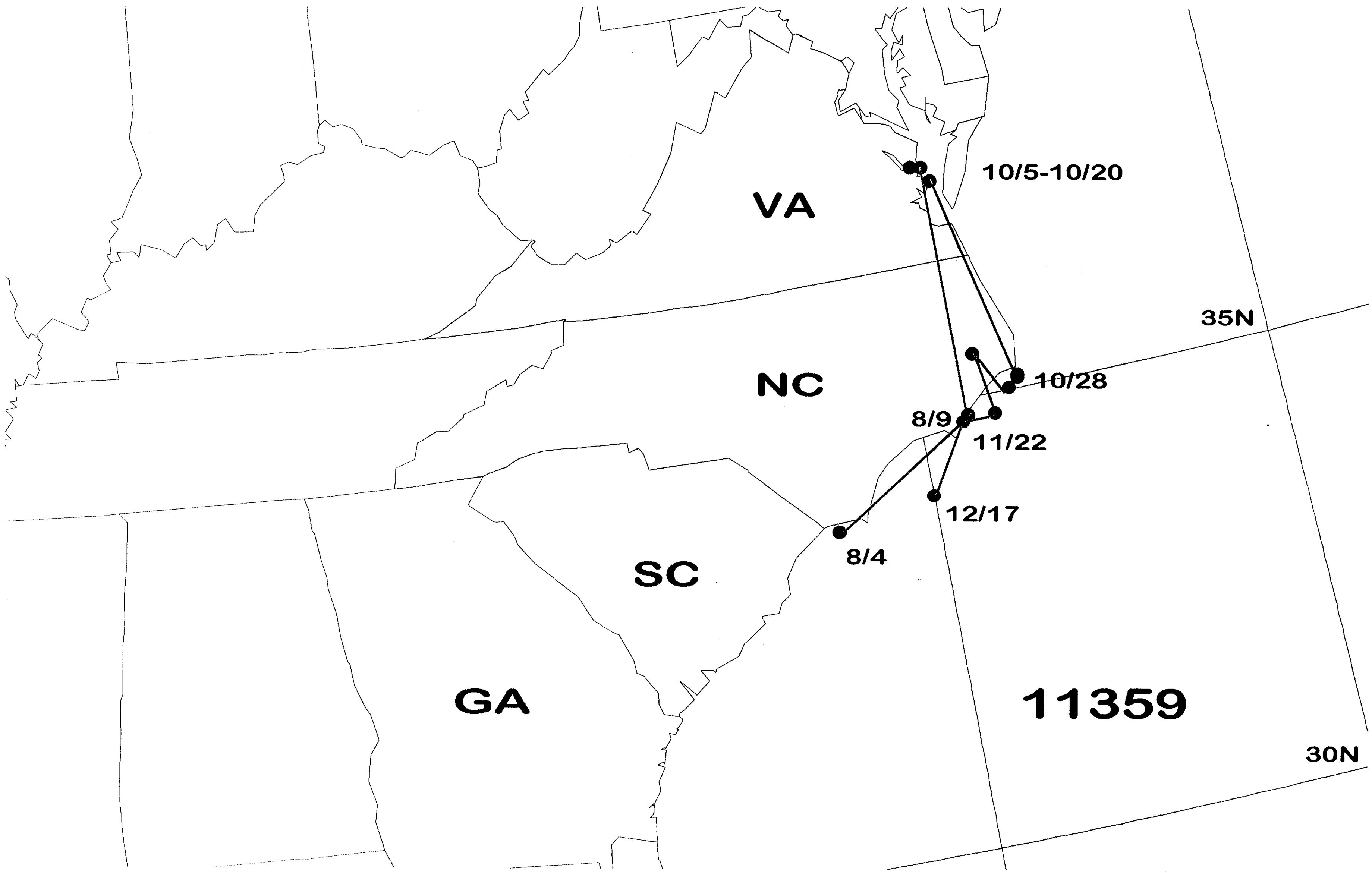

Figure 3

Figure 4

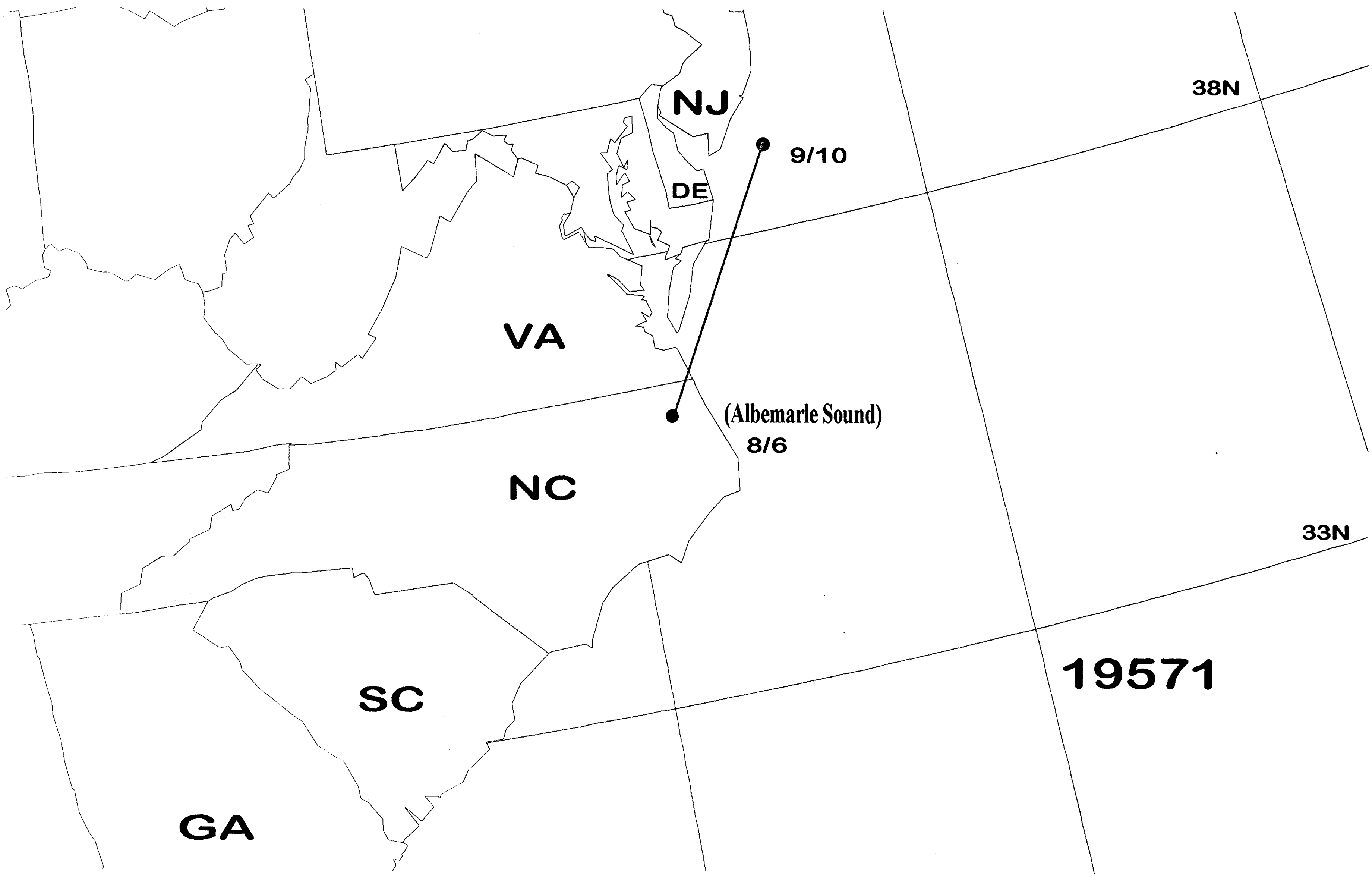

Figure 5

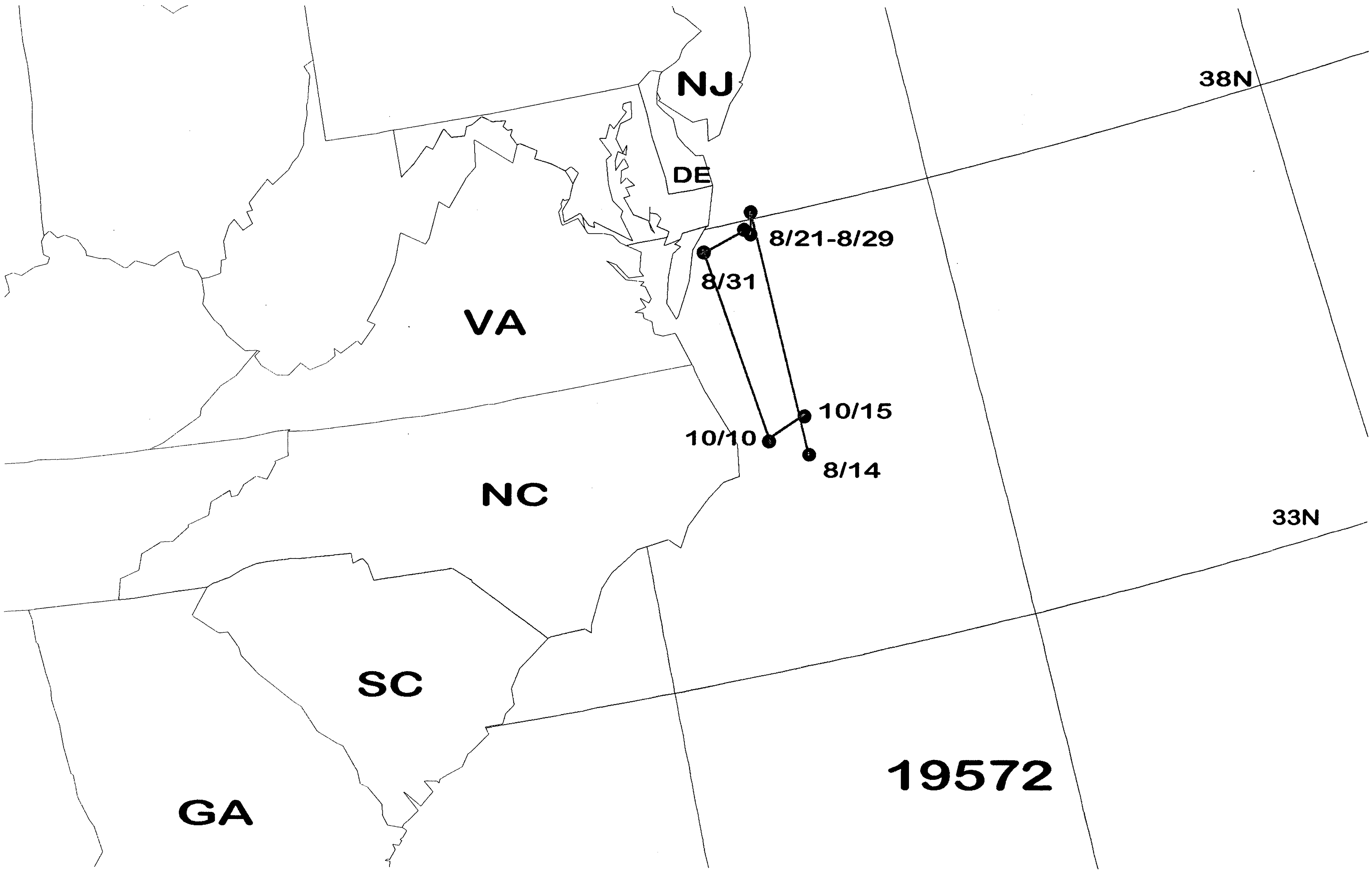

Figure 6